

# ELECTRICAL MOISTURE METERS FOR WOOD

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In Cooperation with the University of Wisconsin

# ELECTRICAL MOISTURE METERS FOR WOOD

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## Introduction

Measurements of the moisture content of wood are made in various ways. For scientific, experimental, and more or less basic measurements, moisture content values are obtained by the oven-drying method. If the wood contains volatile oils that would be given off when heated and be measured as water on a weight basis, the oven-dry method is inaccurate. Where volatile oils are present, either in the natural state or when added by impregnation, a distillation method is used in which the wood sample is placed in a liquid, such as xylol or kerosene, and heated. The moisture is distilled from the sample and collected in a measuring tube. The amount of water in the tube can be read from the scale as it separates out from the oil.

Electrical methods have come into extensive use in commercial control work in the manufacture of wood products and processing of lumber. They make use of such electrical properties of wood as its electrical resistance, dielectric constant, and radio-frequency power loss. Other methods not in common use consist of the measurement of relative humidities that develop in the air adjacent to a wood sample, and of a chemical reaction that removes water from the sample and produces a gas that causes a rise in pressure in an enclosure or a loss in weight of the wood by release of the gas. Paper treated with cobalt chloride indicates by its color the approximate relative-humidity conditions surrounding it.

Electric moisture meters appeared on the American market about 1930. These instruments are designed to provide a quick, easy, and nondestructive quantitative test for moisture in wood. Instruments now available are being used successfully for moisture control in the lumber, veneer, and plywood industries, as well as in plants producing furniture and similar finished products. At least eight different manufacturers are now making electric moisture meters for wood. Most of

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<sup>1</sup>This report was originally prepared by M. E. Dunlap and E. R. Bell, and was revised by W. L. James in 1954 and 1958.

<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

these measure moisture content in terms of the direct-current resistance of the wood, but at least one manufacturer makes an instrument that determines moisture content by measuring the power absorbed by the wood from a high-frequency electric field. Another instrument is designed to detect incorrect moisture content of material moving along a conveyor chain and, through auxiliary equipment, mark or eject the improper material.

Electric moisture meters that use the relation between moisture content and resistance are called the resistance type; those that use the relation between moisture content and dielectric constant are known as the capacity type; and meters using the relation between moisture content and radio-frequency power loss are designated as the radio-frequency power-loss type.

### Resistance-Type Moisture Meter

#### Relation Between Moisture Content and Resistance

The direct-current electrical resistance of wood varies greatly with changes in moisture content below the fiber saturation point. With a change from fiber saturation point to the oven-dry condition, which involves a drop in moisture content from about 30 to 0 percent of the weight of the wood, the resistance increases a millionfold. Throughout this range of moisture content values, a nearly linear reciprocal relationship exists between the logarithm of the electrical resistance and the moisture content. This relation, however, fails to hold for higher values of moisture content. From the fiber saturation point to the complete filling of the coarser capillary structure, at which some woods have more than 200 percent moisture content on the basis of oven-dry weight, the electrical resistance changes less than fiftyfold. Consequently, the evaluation of moisture content by means of a resistance measurement can be done with greater accuracy below the fiber saturation point (about 30 percent) than above it. At very low values of moisture content (below about 5 percent), the resistance becomes so high that it is difficult to measure, especially with portable instruments, and moisture meters are not generally calibrated for these low values. Values of 0.46 megohms at 25 percent moisture content and 22,400 megohms at 7 percent moisture content for Douglas-fir are typical of those below the fiber saturation point. Resistances for other species for moisture content values from 7 to 25 percent are shown in table 1.

#### Electrodes

Wood acts as a resistance element in the electrical circuit of a moisture meter. This requires that contact be made to the wood at two points. The type of contacts and distance between them should be constant for purposes of comparison and calibration, but the distance between contacts is, in practice, not critical.

Generally such contact is made by driving needle points into the wood. Two needles connected by a retaining bar serve for each contact. The bars are mounted on a block of good insulating material, with a handle arranged so that the needles can be easily driven and withdrawn. The points of each pair are usually mounted one-half inch apart on the retaining bar and about 1-1/4 inches between the pairs. The contact length is about five-sixteenths of an inch for a 2-inch dimension (1-5/8 inches in actual thickness), and proportionally longer or shorter for lumber of greater or lesser thickness. Generally the points driven into the wood are oriented so that current will flow parallel to the grain when a moisture content determination is being made.

Contact with thin material, such as veneer, can be made by using many very short needles on each electrode and driving them either into one face or opposite faces of the veneer. It also may be made by clamping surface plates to opposite faces of the veneer, but the reading obtained will be essentially the moisture content of the driest layer within the sheet, usually the surface, not necessarily the average moisture content.

The current flowing between electrodes will follow the path of least resistance, which is also the path with the greatest amount of moisture.

A study of moisture distribution in lumber dried below the fiber saturation point has shown that the average moisture content is usually found at one-fifth the thickness of the piece. When needle-point electrodes are used on wood in which the moisture distribution has been produced by drying, the meter will show the moisture content of the wettest wood contacted by the needle points. Thus, it is possible to determine the moisture content at whatever depth the needles have been driven. This is of great importance wherever moisture content is a vital factor, such as in the treatment of timber with wood preservatives and in the use of heavy timbers for many structural purposes. Nails may be used in place of the regular electrodes when the latter are not long enough to reach the desired depth. Two nails driven about 1-1/4 inches apart are sufficient, but a correction of 1 percent moisture content should be added to the meter reading.

When it is desired to measure the average moisture content of a board that is regaining moisture from its surroundings, the situation is somewhat reversed. In this case, the surface of the board is wetter than the interior, so the needles pass through a wet region into a drier region. The meter still indicates the moisture content of the wettest wood in contact with the electrodes, which will be the surface moisture content, even though this may be much higher than the true average moisture content. To enable operators to make moisture determinations on wood with a reverse (surface wetter than core) gradient, at least one manufacturer is making electrode pins that are covered, except for the extreme tip, with a tough insulating resin. The resin coating insulates the electrode and allows the pin to be driven through a wet surface in order to indicate the true moisture content within the wood. If the surface is actually covered with free water, such as from rain, however, it is probable that some water will follow the tips of the pins into the wood and again produce a wet low-resistance path between the electrodes. Thus, even when insulated pins are used, readings made on wood with free water on the surface should be questioned.

## Range of Moisture Content Values

The range of resistance-type moisture meters for lumber lies between 7 and 25 percent moisture content. One instrument is calibrated for moisture content values from 4 through 120 percent, but, as with all resistance-type moisture meters, the instrument is reliable only through a range of about 7 to 25 percent. In the 7 to 25 percent moisture range, the accuracy of the resistance-type instrument, when properly calibrated and correctly used, should be within  $\pm 1$  percent. It is not expected that readings of moisture content above 25 percent will be as accurate as those in a lower range, nor do they ordinarily need to be. This type of meter is shown in figure 1.

## Capacity and Radio-Frequency Power-Loss Type of Moisture Meter

### Moisture Content and Dielectric Properties of Wood

Both the dielectric constant and the dielectric loss factor of wood depend upon the moisture content of the wood.

If the wood is arranged to be the dielectric in some form of a capacitor, these dielectric properties of the wood will have measurable effects on an electric circuit associated with this capacitor. Indirectly then, the moisture content of the wood has a measurable effect on the electric circuit.

### Principle and Operation of the Capacity or Radio-Frequency Power-Loss Type of Moisture Meter

Only one portable radio-frequency type moisture meter is now in common use in America. This instrument is of the power-loss type, and is illustrated in figure 2. The discussion that follows, while generally applicable to any instrument of this type, is particularly in regard to this one instrument.

In this type of instrument, a vacuum-tube oscillator generates an alternating-current with a frequency of about 10 megacycles per second. This radio-frequency current is applied to electrodes of such geometric arrangement that when these electrodes are pressed against a sample of wood a radio-frequency field is caused to penetrate into the wood. The amount of power absorbed from this field by the wood depends upon the moisture content of the wood. This power is delivered by the oscillator, and variations in the power delivered by the oscillator produce measurable changes in the grid current flowing in this oscillator. The grid current, therefore, is an indication of the moisture content of the wood, so a grid-current meter can be calibrated directly in moisture content. This calibration, however, depends on other factors, such as the species of the wood and its density. Commonly, the meter is directly calibrated for wood of one species, and a conversion table is supplied for use on species other than this one.

## Electrodes

Electrodes are the surface-contact type. They vary in design according to the material for which they are to be used.

## Use on Lumber

Two different electrode arrangements are suitable for use on lumber. One consists of two insulated plates that are placed on opposite faces of the piece under test. In the other, contact is made on one side only with an electrode consisting of a ring of buttons, or four separated quadrants of a disk, or some other geometrical arrangement of surface-contact electrodes. These electrodes are usually spring-loaded to allow good contact even if the surface of the board is uneven. The penetration of the field is about three-fourths of an inch, but as the field is stronger near the electrodes, the wood closest to the electrodes (the surface) has a predominant effect on the reading.

Use on thin material.--A set of electrodes developed especially for veneer has several concentric coplanar rings. The electrical field is concentrated near the plane of the electrodes, and therefore is usable on thin material.

## Range of Moisture Content Values

The range of capacity or power-loss types of moisture meters is from 0 to about 25 percent moisture content.

## Automatic Moisture Control

A new machine has recently appeared that is used for measuring the moisture content of moving lumber, veneer, or paper. In particular, it is designed to mark or reject automatically material with a moisture content improper for use. It is used for sorting lumber or veneer on the dry chain, or inspecting material approaching cutting tables or planers. This machine is a combination of the resistance-type and capacitance-type meter. A typical installation is shown in figure 3.

## Accuracy of Measurements

The most important factors that affect the accuracy of moisture-meter determinations are (1) species, (2) specific gravity, (3) moisture distribution, (4) thickness of material, (5) temperature, (6) contact, (7) grain direction, (8) high relative humidities, (9) number of measurements, (10) the personal element.

Species.--At any given moisture content both the resistance and dielectric properties of wood depend upon the species. The apparent variation between species may be due partly to differences in specific gravity in the case of the capacity or radio-frequency power-loss meters and electrolytes in the case of resistance meters. Most moisture meters are calibrated to read directly for one species. The true value for other common commercial species can be obtained by applying to the meter indication corrections from tables supplied with each instrument.

Specific gravity.--The indications of resistance-type moisture meters appear to be independent of specific gravity.

The indication of capacity or radio-frequency power-loss meters depends upon the specific gravity of wood as well as its moisture content. Since all species contain a considerable range of specific gravities, it is probable that the instrument calibrations are for the average specific gravity of each species. Any moisture content determination, therefore, carries an error proportional to the difference between the specific gravity of the piece being tested and the value used for calibration. The effect of specific gravity may be caused partly by the fact that, at the same moisture content, wood of high specific gravity contains more moisture than wood of low specific gravity.

Moisture distribution.--Surface moisture due to rain, dew, or fog forms a layer with low resistance and high dielectric constant and radio-frequency power absorption. This wet surface would generally cause both types of meter to read too high. A resistance-type meter equipped with electrode pins that are covered except for the extreme tip by a coating of insulating resin, however, can be used to measure the average moisture content, even if the surface is wetter than the interior of the board. The presence of water pockets within the wood would also cause moisture meters to read too high. Insulated pins would not be helpful in this case, but water pockets could be detected by making readings at more than one position on the board. The presence of an unknown moisture gradient may cause errors as noted previously.

Thickness of material.--Electrodes of the resistance-type meter for use with wood up to 1-1/2 inches thick have been described. If the 5/16-inch points are used in material thicker than 1-1/2 inches, the values obtained will be accurate only when the wood has a uniform moisture distribution. If a drying distribution exists, a wet core would not be indicated. It would be preferable to drive two nails to one-fifth the thickness of the wood, and use them for electrodes. The value thus obtained would represent the average moisture content of the wood.

The circular arrangement of spring-cushioned rods and concentric-ring electrodes of the radio-frequency type is available for thick and thin material, respectively. The rod electrodes are for lumber one-half inch or more in thickness. According to information furnished by the maker, the penetration is three-fourths inch to 1 inch. For thicker material, the probability of error increases with the thickness. Concentric-ring electrodes are for material one-eighth to one-half inch thick. Penetration is one-eighth inch. The ring electrodes can also be used on sheets less than one-eighth inch thick when laid on a suitable backing, such as glass, which shows very little radio-frequency power absorption.

Temperature.--As the temperature of wood increases, the electrical resistance decreases and vice versa. The rate of change of resistance with temperature is higher as the moisture content increases. Because of this phenomenon, the readings of resistance-type moisture meters should be corrected if the temperature of the wood is different from the temperature at which the meter was calibrated. This correction can most easily be obtained graphically from a chart, such as figure 4 or 5. Figure 4 is for temperatures below 90° F., figure 5 is for temperature above 90° F. The effect of temperature on the readings of radio-frequency type meters is not accurately known, but as the manufacturers furnish no temperature-correction data, it is assumed that a temperature correction is unnecessary.

Contact.--The needle electrodes of resistance-type meters should be driven the proper distance into sound wood if possible. Surface-type electrodes should be pressed firmly into contact with the wood surface. If poor contact is made with any type of electrode, too low moisture content will be indicated.

Grain direction.--Resistance measured across the grain is slightly greater than that measured along the grain. It is general practice to measure moisture content in terms of resistance in the grain direction. Instructions with each instrument indicate the proper placement of electrodes.

Both the rod and ring electrodes of capacity and radio-frequency power-loss meters have circular symmetry and therefore cannot be affected by grain direction provided all the electrode is covered by wood.

Electrolytes.--When wood is treated with salts for preservative or fire-retarding purposes, the wood becomes more conductive and consequently with any type of electrical moisture meter may indicate a moisture content greater than the correct value. This is also true of some glue lines and measurements of moisture content of plywood specimens may therefore be higher than the actual moisture content.

High relative humidities.--When resistance-type meters are used in wet weather, their surfaces may become damp and provide leakage paths with resistances comparable to those associated with low wood moisture content values, and thus preclude measurements at low moisture content.

The capacity and radio-frequency power-loss meters are not subject to error caused by surface films on the instruments, because effects of surface leakage are eliminated through the initial balance. If the surface leakage is too great, however, initial balance will not be possible.

Number of measurements.--A single measurement should not be depended upon as the true moisture content value of a piece of lumber, if more measurements can be obtained. A representative moisture content value should be an average of at least three determinations whenever possible. This is especially true of a small number of pieces. If an operator is pushed for time, as might be the case when checking a kiln load as it is removed from a kiln, one measurement per board checked may suffice to obtain a good average for the load, provided that a sufficient number of boards are checked.

Personal element.--The accuracy of moisture-meter determinations often depends upon the care with which the instrument is used. Conditions that require measurements to be made rapidly may lead to inaccuracies due to incorrect balancing, reading, location of points, poor contact, neglect of temperature correction, and dependence upon a single measurement. As much care as possible should be exercised in all measurements to obtain reliable values.

If the above factors are considered, and the specific instructions accompanying the instrument carefully followed, an accuracy of  $\pm 1$  percent moisture content can be expected from an electric moisture meter. If measurements are made on lumber that is very wet or, if using a resistance-type meter, very dry, or lumber that is at very high or very low temperatures, the reliability of the readings will be greatly reduced.

## Maintenance

### General Considerations

The maintenance of moisture meters consists largely of replacements of exhausted or broken components. Periodic inspections will minimize the probability of failure while in use. Frequency of inspection will depend upon the amount of use given an instrument.

### Replacements

Portable moisture meters operate on self-contained dry batteries. When partially exhausted, the batteries should be replaced. The need for replacement of batteries is indicated by either a low battery voltage measured with the switch on, or by the inability of an operator to obtain a steady-state balance. The meter will show a constant drift.

Vacuum tubes last for many, perhaps several thousand hours of service. They seldom require replacement.

The needle contacts of resistance-type meters become bent or broken in use. It is advisable to have a number of spare needles and a wrench in the moisture-meter case.

The need for replacement of batteries and contact needles can be minimized by always placing the switch in the OFF position when the instrument is not in use, and by carefully driving and withdrawing the needles with as little bending as possible. Some moisture meters automatically turn off the switch when the instrument case is closed. Rough handling of the instrument should be avoided.

## Makers and Dealers of Electric Moisture Meters<sup>3</sup>

<u>Makers and dealers</u>	<u>Trade name</u>	<u>Type</u>
Coe Manufacturing Co. Painesville, Ohio	Laucks Sentry <sup>4</sup>	Resistance-capacitance combination
A. M. Conway & Son 1623 SE. 6th Ave. Portland 14, Oreg.	Laucks Sentry <sup>4</sup>	Resistance-capacitance combination
Delmhorst Instrument Co. 117 Cornelia St. Boonton, N. J.	Delmhorst Moisture Detector	Resistance
Hart Moisture Gauges, Inc. 126 Liberty St. New York 6, N. Y.	Hart Moisture Gauge and Kaydel Moisture Meter	Resistance
Hart-Moisture-Meters 1948 Grand Central Terminal Bldg. New York 17, N. Y.	Hart Moisture Meter	Resistance
Industrial Instruments, Inc. 156 Culver Ave. Jersey City, N. J.	Megohm Bridge	Resistance
Laucks Laboratories, Inc. 1008 Western Ave. Seattle 4, Wash.	Laucks Sentry <sup>4</sup>	Resistance-capacitance combination
C. M. Lovsted & Co. 4000 Iowa & Marginal Way Seattle, Wash.	Tag-Heppenstall and Moisture Register <sup>5</sup>	Resistance Radio-frequency power-loss
Moisture Register 1510 W. Chestnut St. Alhambra, Calif.	Moisture Register <sup>5</sup>	Radio-frequency power-loss, and Resistance

<sup>3</sup>This list has been prepared for the information of correspondents. The inclusion of names in the list implies no endorsement by the Forest Products Laboratory as to quality of service or cost.

<sup>4</sup>An automatic machine for checking moisture content of moving lumber, veneer, or paper.

<sup>5</sup>Both a resistance type and a radio-frequency type meter are made with the trade name of "Moisture Register."

<u>Makers and dealers</u>	<u>Trade name</u>	<u>Type</u>
Moore Dry Kiln Co. Jacksonville 1, Fla. also North Portland, Oreg.	Tag-Heppenstall Moisture Meter and Moisture Register <sup>5</sup>	Resistance  Radio-frequency power- loss, and Resistance
National Engineering Co. P. O. Box 1475 Indianapolis 6, Ind.	Tag-Heppenstall Moisture Meter and Moisture Register <sup>5</sup>	Resistance  Radio-frequency power- loss, and Resistance
Physics Research Labora- tories, Inc. 507 Hempstead Turnpike West Hempstead, N. Y.	Gann Hydromat	Resistance
Standard Dry Kiln Co. Indianapolis 6, Ind.	Moisture Register <sup>5</sup> Tag-Heppenstall Moisture Meter	Radio-frequency power-loss, and Resistance
Thwing-Albert Instrument Co. Penn St. & Pulaski Ave. Philadelphia 44, Pa.	Thwing-Albert Electronic Moisture Meter	Resistance
Weston Electrical Instrument Corp. Newark, N. J.	Weston (Tag-Heppenstall) Moisture Meter	Resistance
George E. Zweifel 1123 NW. Gilson St. Portland, Oreg.	Moisture Register	Radio-frequency power-loss

## REFERENCES

Davies, I. I.

1937. A Wide-Range Vacuum-Tube Resistance Bridge. Instruments 10:261, illus.

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1937. A Wide-Range Vacuum-Tube Resistance Bridge. U. S. Patent 2,088,843, assigned to U. S. Government for the free use of the public.

Dunlap, M. E.

1945. Methods Used for the Measurement of the Moisture Content of Wood. Proc. ASTM, Committee Reports 45:269.

Keylwerth, von Rudolph, and Noack, Detlef.

1956. Über den Einfluss Hoherer Temperaturen auf die Elektrische Holzfeuchtheitsmessung nach dem Widerstandsprinzip. (Influence of Higher Temperatures on the Electrical Measurement of Moisture Content in Wood When Using the Resistance Principle.) Holz als Roh- und Werkstoff 14(5): 162-172.

Segelken, J. G. and Mason, M. S.

1941. An Electrical Test for Moisture Content in Seasoned Untreated Southern Pine Timber. AWPA Proceedings.

---

1941. An Electrical Test for Moisture Content in Seasoned Untreated Round Southern Pine Timbers. AWPA Proceedings.

Stamm, A. J.

1927. The Electrical Resistance of Wood as a Measure of Its Moisture Content. Ind. & Eng. Chem. 19(9):1021, illus.

---

1930. An Electrical Conductivity Method for Determining the Moisture Content of Wood. Analytical Ed., Ind. & Eng. Chem. 2:240, illus.

Suits, C. G. and Dunlap, M. E.

1930. The "Blinker," An Instrument for Determining Moisture Content of Wood. Amer. Lbrmn. (2877):42, illus.

---

1930. New Instrument for Rapid Moisture Content Determinations in Wood. Instruments 3:(8):538, illus.

---

1931. Determination of the Moisture Content of Wood by Electrical Means. General Electric Review, 706-13.

Tiemann, H. D.

1936. Moisture Meters. South. Lbrmn. 153:41, illus.

Tiemann, H. D.

1936. Electric Moisture Meters. South. Lbrmm. 153:205, illus.

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1937. Electric Moisture Meters. South. Lbrmm. 154:35, illus.

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1937. Electric Moisture Meters. South. Lbrmm. 154:31, illus.

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1937. Electric Moisture Meters. South. Lbrmm. 154:49, illus.

---

1937. Miscellaneous Commercial Moisture Meters. South. Lbrmm. 154:39, illus.

---

1937. Miscellaneous Commercial Moisture Meters. South. Lbrmm. 154:33, illus.

---

1937. What's New in Electric Moisture Meters. South. Lbrmm. 155:44, illus.

Tombach, Harold

1954. The Electric Moisture Meter for Wood: How to Choose It and What to Expect of It. South. Lbrmm. 188(2347)63-72.

Table 1.--The average electrical resistance along the grain in megohms, measured at 80° F. between two pairs of needle electrodes 1-1/4 inches apart and driven to a depth of 5/16 inch, of several species of wood at different values of moisture content.

Species of wood	Moisture content in percent																			
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Conifers:																				
Baldcypress.....	12,600:	3,980:	1,410:	630:	265:	120:	60:	33:	18.6:	11.2:	7.1:	4.6:	3.09:	1.78:	1.26:	0.91:	0.66:	0.51:	0.42:	
Douglas-fir (coast region)...	22,400:	4,780:	1,660:	630:	265:	120:	60:	33:	18.6:	11.2:	7.1:	4.6:	3.09:	2.14:	1.51:	1.10:	.79:	.60:	.46	
Fir, California red.....	31,600:	6,760:	2,000:	725:	315:	150:	83:	48:	28.8:	18.2:	11.8:	7.6:	5.01:	3.31:	2.29:	1.58:	1.15:	.83:	.63	
Fir, white.....	57,600:	15,850:	3,980:	1,120:	415:	180:	83:	46:	26.9:	16.6:	11.0:	6.6:	4.47:	3.02:	2.14:	1.55:	1.12:	.86:	.62	
Hemlock, western.....	22,900:	5,620:	2,040:	850:	400:	185:	98:	51:	28.2:	16.2:	10.0:	6.0:	3.89:	2.52:	1.58:	1.05:	.72:	.51:	.37	
Larch, western.....	39,800:	11,200:	3,980:	1,445:	560:	250:	120:	63:	33.9:	19.9:	12.3:	7.6:	5.02:	3.39:	2.29:	1.62:	1.20:	.87:	.66	
Pine, longleaf.....	25,000:	8,700:	3,160:	1,320:	575:	270:	135:	74:	41.7:	24.0:	14.4:	8.9:	5.76:	3.72:	2.46:	1.66:	1.15:	.79:	.60	
Pine, white.....	20,900:	5,620:	2,090:	850:	405:	200:	102:	58:	33.1:	19.9:	12.3:	7.9:	5.01:	3.31:	2.19:	1.51:	1.05:	.74:	.52	
Pine, ponderosa.....	39,800:	8,910:	3,310:	1,410:	645:	300:	150:	81:	44.7:	25.1:	14.8:	9.1:	5.62:	3.55:	2.34:	1.62:	1.15:	.87:	.69	
Pine, shortleaf.....	43,600:	11,750:	3,720:	1,350:	560:	255:	130:	69:	38.9:	22.4:	13.8:	8.7:	5.76:	3.80:	2.63:	1.82:	1.29:	.93:	.66	
Pine, sugar.....	22,900:	5,250:	1,660:	645:	280:	140:	76:	44:	25.7:	15.9:	10.0:	6.6:	4.36:	3.02:	2.09:	1.48:	1.05:	.75:	.56	
Redwood.....	22,400:	4,680:	1,550:	615:	250:	100:	45:	22:	12.6:	7.2:	4.7:	3.2:	2.29:	1.74:	1.32:	1.05:	.85:	.71:	.60	
Spruce, Sitka.....	22,400:	5,890:	2,140:	830:	365:	165:	83:	44:	25.1:	15.5:	9.8:	6.3:	4.27:	3.02:	2.14:	1.58:	1.17:	.91:	.71	
Hardwoods:																				
Ash, white <sup>1</sup> .....	12,000:	2,190:	690:	250:	105:	55:	28:	14:	8.3:	5.0:	3.2:	2.0:	1.32:	.89:	.63:	.50:	.44:	.40:	.40	
Basswood <sup>1</sup> .....	36,300:	1,740:	470:	180:	85:	45:	27:	16:	9.6:	6.2:	4.1:	2.8:	1.86:	1.32:	.93:	.69:	.51:	.39:	.31	
Birch <sup>1</sup> .....	87,000:	19,950:	4,470:	1,290:	470:	200:	96:	53:	30.2:	18.2:	11.5:	7.6:	5.13:	3.55:	2.51:	1.78:	1.32:	.95:	.70	
Elm, American.....	18,200:	2,000:	350:	110:	45:	20:	12:	7:	3.9:	2.3:	1.5:	1.0:	.66:	.48:	.42:	.40:	.40:	.40:	.40	
Hickory <sup>1</sup> .....	31,600:	2,190:	340:	115:	50:	21:	11:	6.3:	3.7:	2.3:	1.5:	1.00:	.71:	.52:	.44:	.40:	.40:	.40:	.40	
Khaya <sup>2</sup> .....	44,600:	16,200:	6,310:	2,750:	1,260:	630:	340:	180:	105.0:	60.2:	35.5:	21.9:	14.10:	9.33:	6.16:	4.17:	2.82:	1.99:	1.44	
Magnolia <sup>1</sup> .....	43,700:	12,600:	5,010:	2,040:	910:	435:	205:	105:	56.2:	29.5:	16.2:	9.1:	5.25:	3.09:	1.86:	1.17:	.74:	.50:	.32	
Mahogany, (Swietenia).....	20,900:	6,760:	2,290:	870:	380:	180:	85:	43:	22.4:	12.3:	7.2:	4.4:	2.69:	1.66:	1.07:	.72:	.49:	.35:	.26	
Maple, sugar.....	72,400:	13,800:	3,160:	690:	250:	105:	53:	29:	16.6:	10.2:	6.8:	4.5:	3.16:	2.24:	1.62:	1.23:	.98:	.75:	.60	
Oak, northern red <sup>2</sup> .....	14,400:	4,790:	1,590:	630:	265:	125:	63:	32:	18.2:	11.3:	7.3:	4.6:	3.02:	2.09:	1.45:	.95:	.80:	.63:	.50	
Oak, white.....	17,400:	3,550:	1,100:	415:	170:	80:	42:	22:	12.6:	7.2:	4.3:	2.7:	1.70:	1.15:	.79:	.60:	.49:	.44:	.41	
Philippine mahogany (Shorea spp.).....	2,890:	690:	220:	80:	35:	15:	9:	5:	2.8:	1.7:	1.1:	.7:	.45:	.30:	.21:	.16:	.12:	.09:	.07	
Sweetgum.....	38,000:	6,460:	2,090:	815:	345:	160:	81:	45:	25.7:	15.1:	9.3:	6.0:	3.98:	2.63:	1.78:	1.26:	.87:	.63:	.46	
Tupelo, black <sup>2</sup> .....	31,700:	12,600:	5,020:	1,820:	725:	275:	120:	58:	27.6:	13.0:	6.9:	3.7:	2.19:	1.38:	.95:	.63:	.46:	.33:	.25	
Walnut, black.....	51,300:	9,770:	2,630:	890:	355:	155:	78:	41:	22.4:	12.9:	7.3:	4.9:	3.16:	2.14:	1.48:	1.02:	.72:	.51:	.38	
Yellow-poplar <sup>2</sup> .....	24,000:	8,320:	3,170:	1,260:	525:	250:	140:	76:	43.7:	25.2:	14.5:	8.7:	5.76:	3.81:	2.64:	1.91:	1.39:	1.10:	.85	

<sup>1</sup> Exact species unknown.

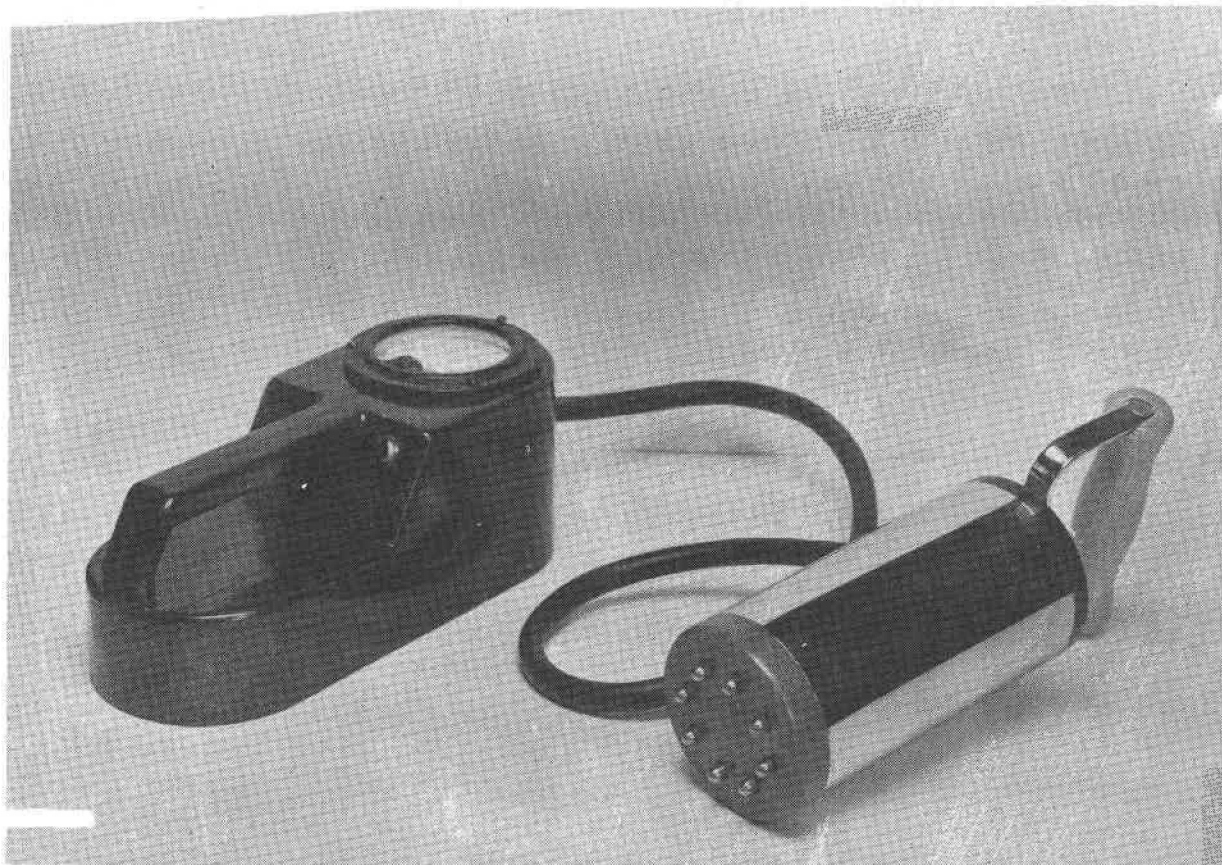
<sup>2</sup> Known in the trade as "African mahogany."

<sup>3</sup> The values for this species were calculated from measurements on veneer.



Figure 1.--Resistance-type moisture meter.

ZM 68017 F



**Figure 2.--Capacity or radio-frequency power-loss type moisture meter.**

Z M 75142 \*



Figure 3.--Typical installation of a machine used to measure the moisture content of moving lumber, veneer, or paper.

Z M 96878 F

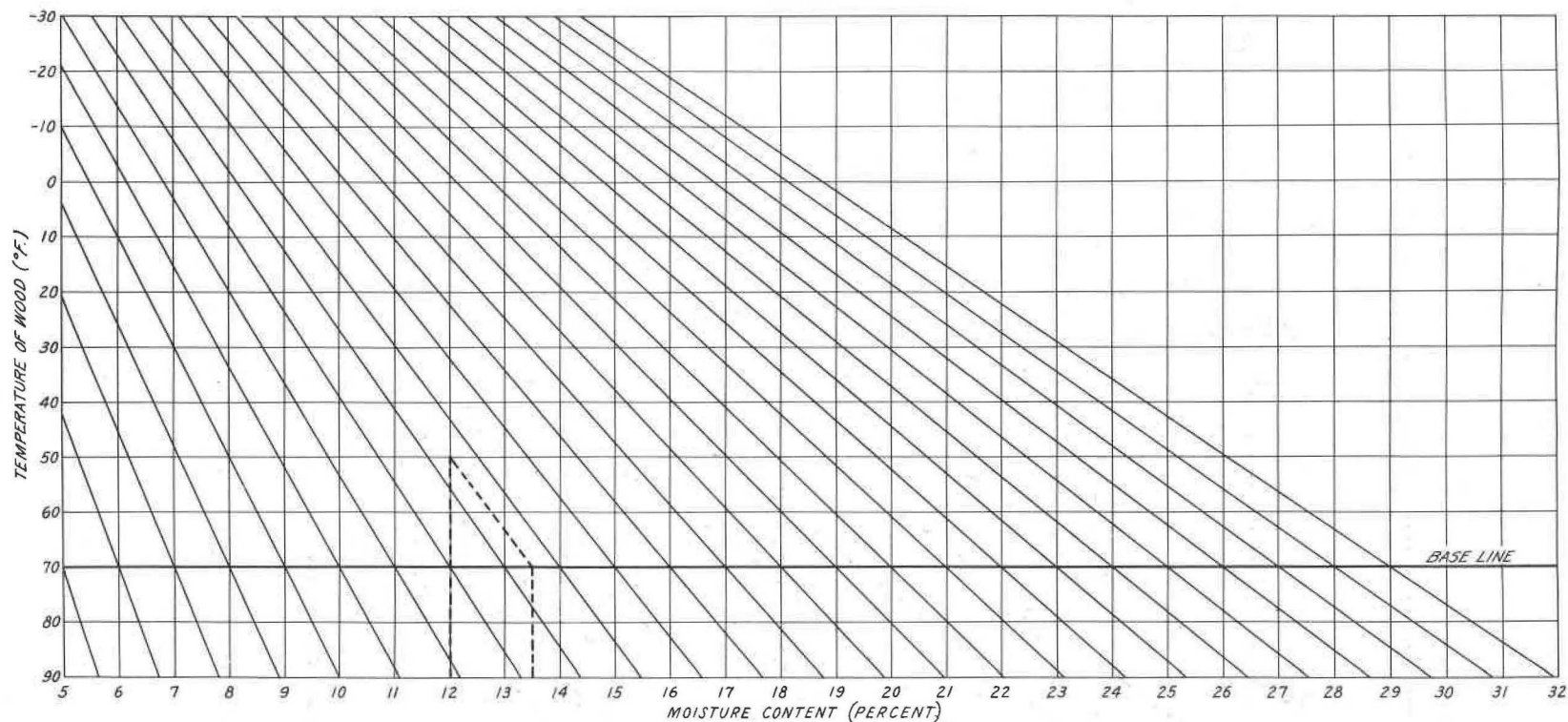


Figure 4. --Temperature corrections applicable to moisture content determined with resistance type electric moisture meters. Find the moisture content indicated by the moisture meter on the lower margin of the diagram, follow this line vertically to the horizontal temperature line approximating the temperature of the wood being tested, then follow the sloping lines to the 70° F. base line and read the corrected moisture content vertically below. Example: measured moisture content, 12 percent, temperature of wood, 50° F., corrected moisture content, 13.5 percent. If the meter was calibrated at a temperature different from 70° F., the base line should be at the actual calibration temperature, not 70° F.

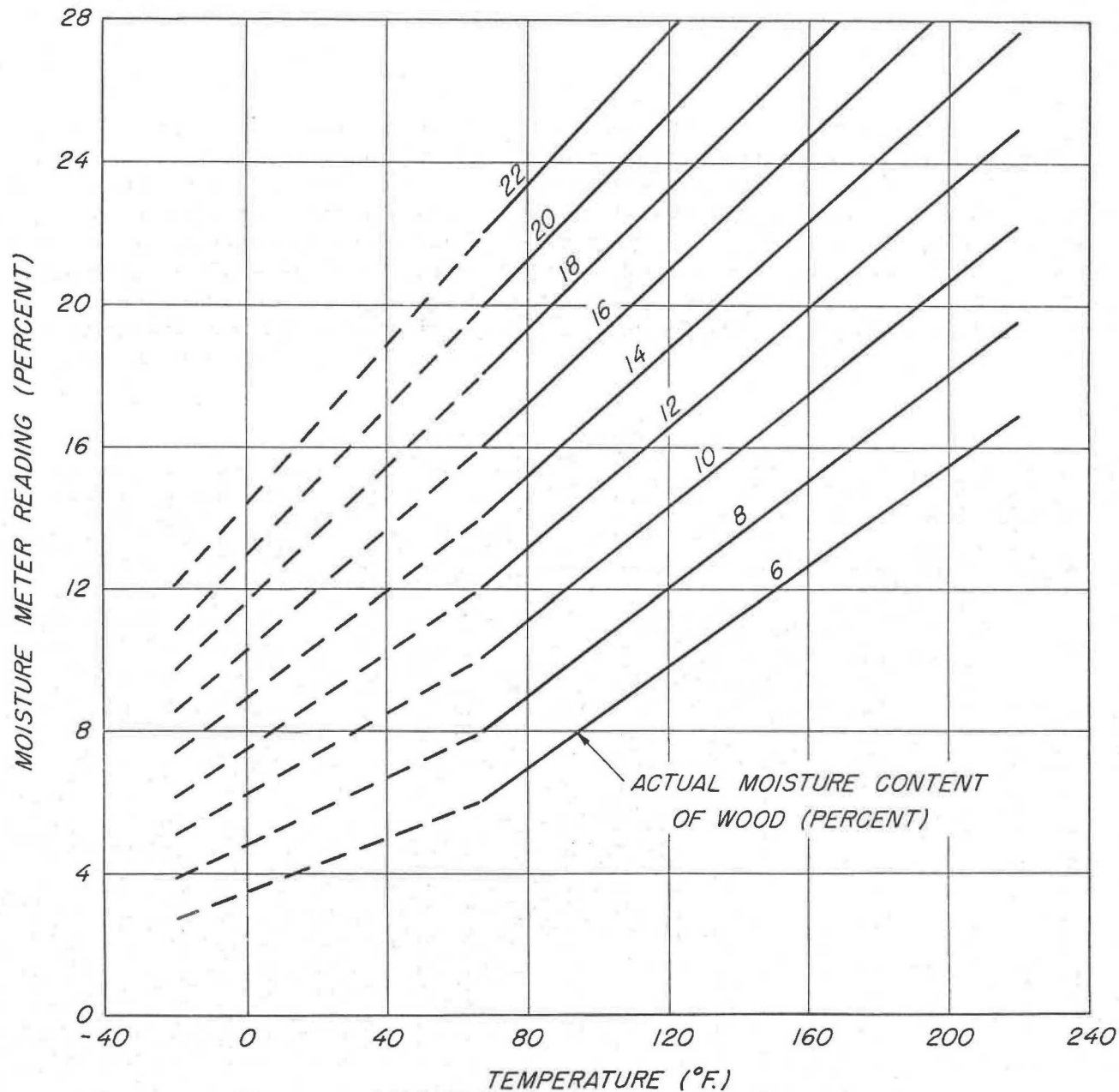


Figure 5. --Temperature correction chart for resistance-type moisture meters for wood (data by Keylwerth and Noack, published in Holz als Roh- und Werkstoff, May 1956).